Appendix A

Behavior of a Constant Fraction Discriminator

Constant Fraction Discriminators (CFD) were used for PM3 and PM4 in order to reduce time walk. Looking at the time walk of PM4 in Figure 5.8, a clear time walk (Δt_{PM4}) shows up for low ADC values, while for ADC values larger than 200 the Δt_{PM4} is almost independent of the ADC value. The CFD seems to behave like a normal discriminator for ADC values smaller than 200. Note that the time walk for ADC $>$ 200 is less than 100 ps (apart from the last point), which is within specification of the Ortec type 934 CFD [125] (150 ps).

The dual behavior can be explained by looking in some detail at the operation of a CFD. Figure A.1 shows the basic functionality of an Ortec type 934. The input signal

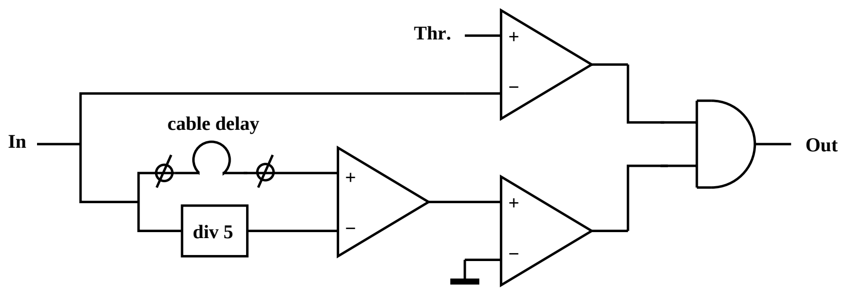

Figure A.1: *Basic functional diagram of a constant fraction discriminator.*

from the photomultiplier is supplied to two circuits, a normal (threshold) discriminator and a constant fraction discriminator. An output pulse is produced from the logic AND of the normal discriminator and the CFD. The output timing of the normal discriminator shows time walk and it should only act as enable for the CFD-output.

The operation of the CFD part is explained with the help of Fig. A.2. The input signal is split in two parts. One part is attenuated by a factor 5 and subtracted from the delayed input pulse. The amount of delay is selectable by cable. Figure A.2 shows that the resulting bipolar signal crosses the baseline at a fixed, but selectable, time with respect to the start of the pulse. The operation principle of the CFD part does not depend on the selected cable delay. However, the cable delay should be chosen such that the output of the CFD determines the timing of the logic AND. If the cable delay is

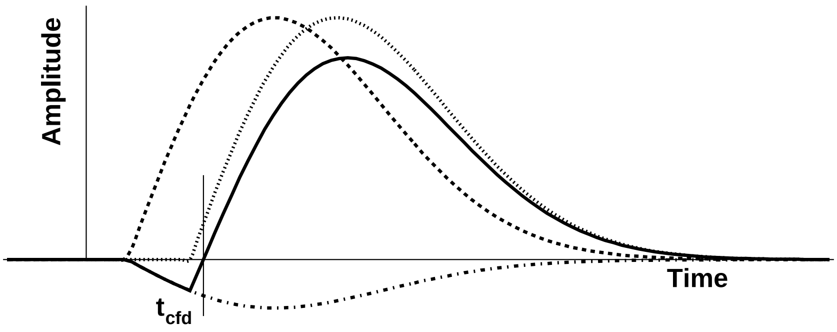

Figure A.2: *Operation of the* CFD*. The input pulse (dashed curve) is delayed (dotted) and added to an attenuated inverted pulse (dash-dot) yielding a bipolar pulse (solid curve). The output of the* CFD *fires when the bipolar pulse changes polarity which is indicated by time* t_{cfd}.

too short, the unit will work as a normal discriminator for signals with a low amplitude because then the output of the normal discriminator fires later than the CFD part. This effect is depicted in Figure A.3. The two dashed curves are the signals going into the

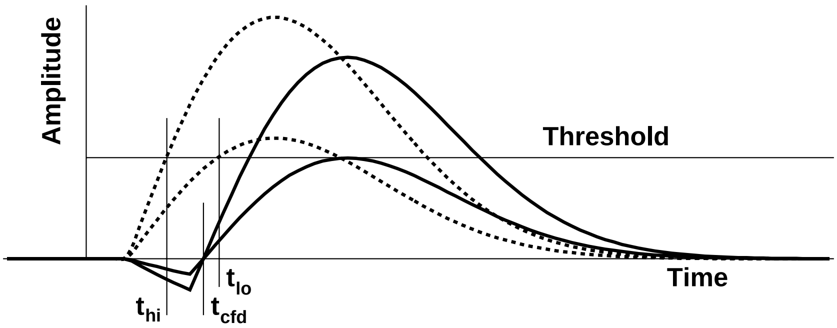

Figure A.3: *The moment at which the threshold discriminator fires depends on the amplitude of the pulse. If the cable delay of the* CFD *is too short, the* CFD *fires too early* (t_{cfd})*. For small input pulses, the timing is determined by the threshold discriminator and not by the* CFD *part.*

threshold discriminator whose output exhibits time walk. For a small input pulse, the threshold discriminator fires at t_{lo} which is later than t_{cfd}, and as a result the output of the CFD unit shows time walk. For large input pulses, the threshold discriminator output fires earlier than t_{cfd}, and no time walk will occur.

Hence, the observed behavior of PM3 and PM4 is probably caused by a too short cable delay. Selection of the cable delay for the CFD was done *before* the experiment with the help of a radioactive source using short coaxial cables for the connection of the photomultiplier to the CFD. At CERN long coaxial cables ($>$ 50 meter) were used which give rise to dispersion of the signals. Dispersion will increase the peaking time of the signals which should have been compensated by increasing the length of the delay cable. This retuning of the delay cables was accidentally omitted.

Appendix B

Noise correlation in strip clusters

For dE/dx based particle identification, the total deposited energy should be known and therefore the signal in a cluster of three strips is accumulated. However, not only the signal but also the noise adds up. Because the noise sources in the three different amplifiers, which are the main contributors to the noise, are uncorrelated a total noise of $\sqrt{3}$ times the noise in a single strip is expected. However, the observed noise in a three channel cluster is smaller than expected which implies a non-zero (negative) covariance of noise sources. This is caused by the cross coupling of the readout amplifiers as will be explained below.

An example of the ratio of the noise in a cluster of three adjacent strips and the noise in a single strip is shown for one the LW modules in the left plot of Fig. B.1. The horizontal line indicates a ratio of $\sqrt{3}$ which corresponds to the addition of three uncorrelated noise sources of equal magnitude. The right hand side of Fig. B.1 shows

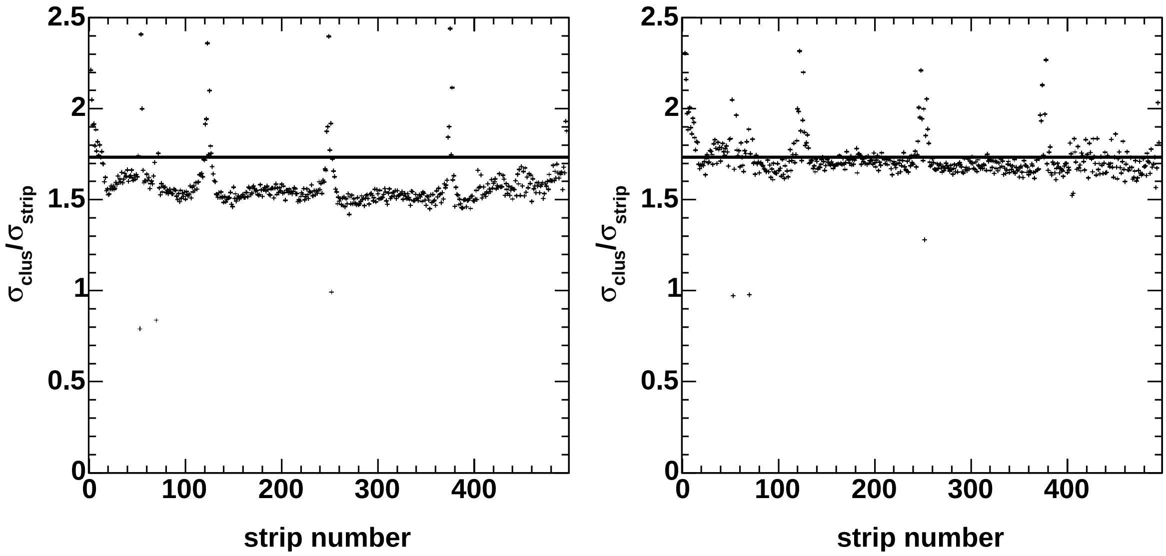

Figure B.1: *Sum of the noise in three adjacent strips (left) and three non-adjacent strips (right). The horizontal line at $\sqrt{3}$ indicates the sum of the noise from three uncorrelated sources of equal magnitude. The noise in three adjacent strips is correlated.*

the sum of the noise in three strips that are not adjacent but have a distance of two strips. In this case the noise is close to the expected level.

The observed difference for the sum of the noise in three adjacent strips can be explained by looking in some detail into the coupling of the electronics to the detector strips. Figure B.2 shows a simplified diagram of this coupling. The diagram only shows the dominant voltage noise sources. A complete treatment of noise sources is given in [126].

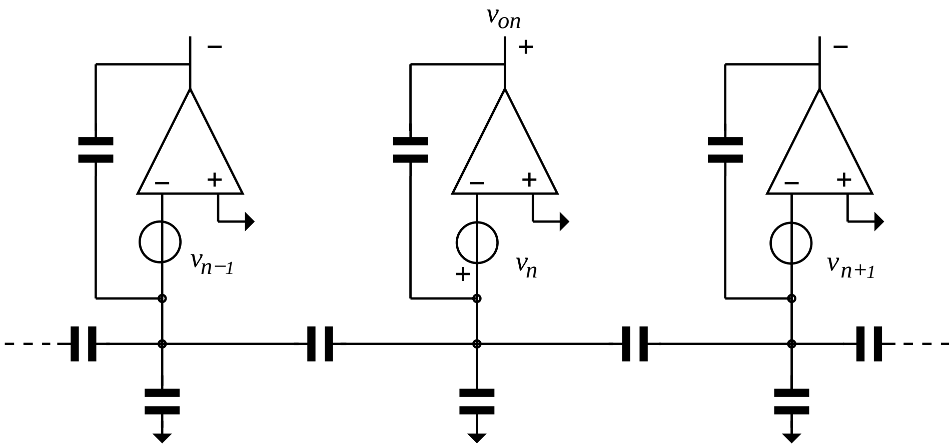

Figure B.2: *Simplified schematic diagram of the coupling between different preamplifiers. The dominant voltage noise source is indicated by v_n.*

The *ac* voltage noise source in the center channel, denoted by v_n, introduces a voltage $k_1 \cdot v_n$ on the output of amplifier n, where the gain factor k_1 depends on the impedances of the network elements. Superimposed on this noise voltage from the amplifier itself is a noise contribution from sources v_{n+1} and v_{n-1}. These contributions are amplified by a factor k_2, where k_2 is, in general, much smaller than k_1[1]. Hence, the noise voltage at the output of amplifier n can be expressed as

$$v_{on} = k_1 \cdot v_n - k_2 \cdot v_{n-1} - k_2 \cdot v_{n+1}. \tag{B.1}$$

The minus signs are due to fact that amplifier n acts as a non-inverting amplifier as seen from voltage source v_n and as an inverting amplifier when looking from v_{n-1} and v_{n+1}. Assuming equal magnitudes (σ) for all noise sources, the magnitude of the noise voltage at the output of amplifier n is

$$\sigma_{on} = \sigma\sqrt{k_1^2 + 2 \cdot k_2^2}. \tag{B.2}$$

Similarly, amplifiers $n+1$ and $n-1$ pick up noise from its neighbors. If we add up the (noise) signal in three neighboring strips, the noise voltage in the cluster becomes

$$\begin{aligned} v_{cl} \;=\; & k_1 \cdot v_n - k_2 \cdot v_{n-1} - k_2 \cdot v_{n+1} + \\ & + k_1 \cdot v_{n-1} - k_2 \cdot v_{n-2} - k_2 \cdot v_n + \\ & + k_1 \cdot v_{n+1} - k_2 \cdot v_n - k_2 \cdot v_{n+2}. \end{aligned} \tag{B.3}$$

[1]The maximum value of gain factor k_2 is $0.5k_1$.

The corresponding noise magnitude is then given by

$$\sigma_{cl} = \sigma\sqrt{3k_1^2 + 6k_2^2 - 8k_1k_2}. \tag{B.4}$$

The first two terms give the noise in case the noise voltages at the amplifier outputs are totally uncorrelated. The third term accounts for the reduction of the noise in a cluster. Because of the non-zero coupling between different amplifiers, which is expressed by a non-zero value of k_2, the noise in a cluster of three strips is less than $\sqrt{3}$ times the noise in a single strip.